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DEPARTMENT OF THE ARMY
OFFICE OF THE DEPUTY CHIEF OF STAFF FOR
RESEARCH, DEVELOPMENT, AND ACQUISITION
WASHINGTON, D. C. 20310

REPORT OF THE ARMY SCIENTIFIC ADVISORY PANEL AD HOC GROUP ON

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REMOTELY PILOTED VEHICLES (RPVs)

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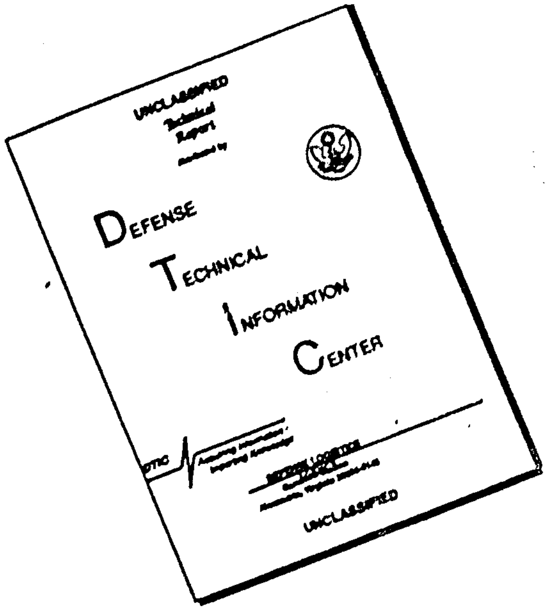

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Army Scientific Advisory Panel

Ad Hoc Committee on RPV

FINAL REPORT

September 1977

SUMMARY

The Army's Remotely Piloted Vehicle (RPV) Program has been reviewed. This review covers the present AQUILA Program which is directed at the provision of a demonstrator vehicle for evaluation of the utility of an RPV for reconnaissance, surveillance, target acquisition/designation (RSTAD). It also examines the adequacy of the available technology and ongoing development effort for implementing a daylight TV/laser-equipped mini-RPV suitable for operation in the battlefield environment. Finally, it looks into future potential uses by the Army of an RPV capability and the technology developments which will pace this use.

Conclusions and Recommendations -

1. The conduct of the AQUILA Demonstration Program is strongly endorsed. Every effort should be directed at maintaining the pace of this phase of the program in view of the impact the TRADOC user evaluation should have on the future phases of the program.

2. Favorable TRADOC evaluation is anticipated with the result of upgrading the priority placed on the mini-RPV program. The technological base of the next phase--the engineering development of an operational prototype--has been well laid. <u>However</u>, concern is expressed at the adequacy of the contractural approach for the next phase. A commitment to a single contractor at the outset of the engineering development phase is a high-risk approach which may not fully exploit the learning and experience derived from the AQUILA Program.

It is recommended that the above budget contractual plans be reviewed if the TRADOC evaluation verifies the anticipated high potential of RPV operational use.

3. Future evolutionary developments and added uses of an RPV have received relatively little consideration. These uses will probably be based on additional sensors and payloads for which the basic technology either exists or is under development. Adaptation to a mini-RPV should not represent a critical path so deferment of this effort for the present should not cause eventual delay.

However, an expansion of the Army's systems studies for incorporation of an RPV capability for battlefield use is strongly recommended. At present, there appears to be a complete lack of such overall systems studies. Such studies should contribute both to the utilization of the initial daylight RSTAD use of RPV's and provide a basis for assessment of broader use of a new and unique capability.

* * * *

INTRODUCTION

This Ad Hoc Committee was established and tasked to review the Army's Remotely Piloted Vehicle (RPV) Program. The background which led to this study, its Terms of Reference, and the Committee membership are shown in Attachment A.

The Army's RPV Program as currently planned is to transition from advanced development to engineering development in the FY 78-79 time period, with initial deployment in the early 1980's. Prior to engineering development, the AQUILA test bed RPV is to be used by TRADOC and DARCOM to gain experience with RPV operations and to develop concepts of operations to be used in writing a Required Operational Capability (ROC) on which the engineering development will be based.

The Terms of Reference (Attachment A) specified the following scope for the ad hoc study.

"Consider:

a. The mission requirements, present and potential.

b. The state-of-the-art for mini-RPV technology.

c. Alternate payloads for RPV's to perform the mission requirements.

d. Alternate solutions for meeting second generation RPV mission requirements.

e. Review of other Service programs."

In the conduct of its study, the Ad Hoc Committee held four two-day meetings in which it was briefed by representatives of the Army RPV Program staff and supporting elements within AVSCOM; the AQUILA Contractor (Lockheed); Project Seeker and the Systems Analysis Activity of TRADOC; DARCOM Battlefield Systems Integration; and Navy, Air Force and United Kingdom RPV Program. Flights of the AQUILA test vehicle and of an Otter airplance with a TV/laser sensor were also observed at Fort Huachuca. By way of these briefings, the Committee was exposed not only to the viewpoints of those directly involved in the RPV development, but also its potential users and planners for more advanced uses.

It is important to note that the study and this report considers the Program from two viewpoints. The first is the present program; the second is the future program required to realize the RPV's full potential. This is of significance because of the background which preceded the present study. In two previous ASAP reviews, it was noted that the Army's

RPV Program was unduly diffuse. Each of these reports recommended a focusing of effort on initial objectives commanding first priority. As noted in the section of this report titled *"Present Program"* this has been done, and the present study strongly endorses this action. On the other hand, it has resulted in delaying effort from developments of importance to the realization of the future potential of RPV's. The section on *"Future Program"* deals with this aspect of the total program.

ATTACHMENT A

Terms of Reference
Army Scientific Advisory Panel
Ad Hoc Group on Remotely Piloted Vehicles

November 1976

1. Background:

The Army RPV program envisaged the RPV program transitioning from advanced development to engineering development in the FY 78-79 time period, with an initial deployment in the early 1980's. Prior to engineering development, the AQUILA test bed RPV is to be used by TRADOC and DARCOM to gain experience with RPV operations and to develop concepts of operations to be used in writing a Required Operationsl Capability (ROC). Some desired Operational Capabilities and potential RPV missions are included as Inclosure 1.

The AQUILA program experienced technical problems during the initial flight test period which resulted in the loss of eight RPVs. The primary problem was in safe retrieval of the RPV (as opposed to launch or normal flight). Seven successful flights have been conducted since the the recovery system was changed in September.

2. Terms of Reference: Perform an in-depth review of the RPV program.

Consider:

a. The mission requirements, present and potential.

b. The state-of-the-art for mini-RPV technology.

c. Alternate payloads for RPVs to perform the mission requirements.

d. Alternate solutions for meeting 2nd generation RPV mission requirements.

e. Review other Service programs.

3. Termination of Effort: The chairman of the ad hoc group is requested to conclude his efforts and provide an interim report. The interim report should clearly define major problems and progress achieved. The final report, due no later than 1 May 1977, should place primary emphasis on the long-term program. The final report should address the level of effort required for all alternatives.

Personnel:

Chairman: Dr. Harry J. Goett
Members: Professor Howard C. Curtiss, Jr.
Mr. Milton Lohr
Dr. George F. Smith

Missions (Grouped by Priority)

Platform for target acquisition and target designator

Platform for gathering intelligence

Platform for communications relay between air and ground, ground and ground.

Weapons platform

Navigation aid

Electronic warfare

Capabilities

Stability satisfactory for laser designator and good optical clarity/resolution

Low cross section to all means of detection

Range in excess of 20 Km

Able to remain on station for extended period (in excess of one hour)

Payload capacity greater than 15 Kg

High probability of survival in combat environment

Low initial cost

Low maintenance requirement

Capable of being deployed with forward tactical elements

Capable of being integrated into current fire control, fire support, and command and control systems.

Enclosure 1

PRESENT PROGRAM

Program Objectives and Management.

Finding -

The present program is well forcused on its twin objectives of providing a demonstration RPV for TRADOC tests, and to follow on with the engineering development of an operational RPV with daytime TV, laser target designation, and ranging for the field. This effort is being directed by an RPV Development Manager's Office which makes effective use of the Army's in-house capabilities and accesses technology developments of other programs which are pertinent to its requirements.

Conclusions and Recommendations -

The recommendations of the prior ASAP Ad Hoc Study have been implemented and the directions of the Letter of Agreement are being followed. The Development Manager's Office which directs this effort is understaffed considering the diversity of the effort and the number of organizations involved. This situation will be aggravated in the upcoming phase of the program when more of the work will be done by outside contractors, rather than by in-house groups.

It is, therefore, recommended that the Central Weapons Systems Group which directs this program be increased in staff and perhaps upgraded to Program Office status.

Discussion -

The Army's RPV Program which is considered in this report as the "Present Program" consists of that established by the Letter of Agreement updated and transmitted by correspondence dated 21 October 1976 for the investigation of a Remotely Piloted Vehicle (RPV) Development Program. The Program, as stipulated in the LOA, consists of the development of "a lightweight, remotely piloted vehicle (RPV) that can provide real- or near-real-time combat intelligence, target acquisition, conduct artillery fire adjustment and laser designation of tank size targets."

The design objectives were spelled out in the LOA and were limited to a sensor package consisting of a (daylight) TV sensor with an auto-tracker capability and laser rangefinder, and a laser-designator for laser guided munitions.

The DARCOM was authorized to develop, test, and provide this basic RPV system for TRADOC evaluation. TRADOC was to evaluate these RPV's to develop operational concepts and determine their tactical feasibility and utility. If the system concept proved both technically and tactically feasible, DARCOM and TRADOC are to establish a Required Operational Capability (ROC) as a basis for the engineering development of an operational vehicle. This program has been executed by way of Lockheed Missiles and Space Company as the AQUILA contractor, and has now been accepted by the Army for evaluation.

The essential elements of the AQUILA "system" are shown in Figs. 1 and 2. It is emphasized that it is a "system" and not just an RPV. The launch, recovery, communications, navigation, automatic control and sensors--derived from a number of available technology programs--have been integrated into a compatible total system. In accordance with the initial plan, it is a "soft" system, capable of operating in the relatively benign environment of the TRADOC user test, but it is not a prototype for an operational vehicle.

The foregoing stepwise approach is strongly endorsed. It places chief emphasis on expediting the evaluation by the user of a system which will potentially represent a quantum improvement in the Army's capability for artillery adjustment beyond direct line of sight. In the likely event that this potential will be verified by the TRADOC tests, the system can be upgraded for the battlefield environment. Future potential uses have been deferred in accordance with this approach (see "Future Program" for discussion of this deferment decision). First priority, plus a focus of effort imposed by budget limitations, has been placed on getting a demonstration vehicle in the hands of the user.

It is to be noted in passing that the above focus of effort is consistent with the recommendation of two past RPV Program Reviews by the ASAP. The April 1974 Report of the Ad Hoc Committee on RPV's emphasized the need for convincing the <u>user</u> of the utility of RPV's and stated that "user involvement (in the program) is not only desirable but mandatory." The LOA strongly reflects recommendations made in this report to achieve this end. This report also stated that many of "the technology areas (for an RPV) need development only in a systems sense, since it is the interaction of the various requirements that require study, and those can be most usefully studied in the systems context."

The more recent ASAP comments in the Summer Study of 1976 were critical of the breadth of the program in relation to its funding and schedule, and recommended termination of "development of RPV payloads not in direct support of day or night target acquisition and designation."

FIGURE 1

AQUILA OVERVIEW

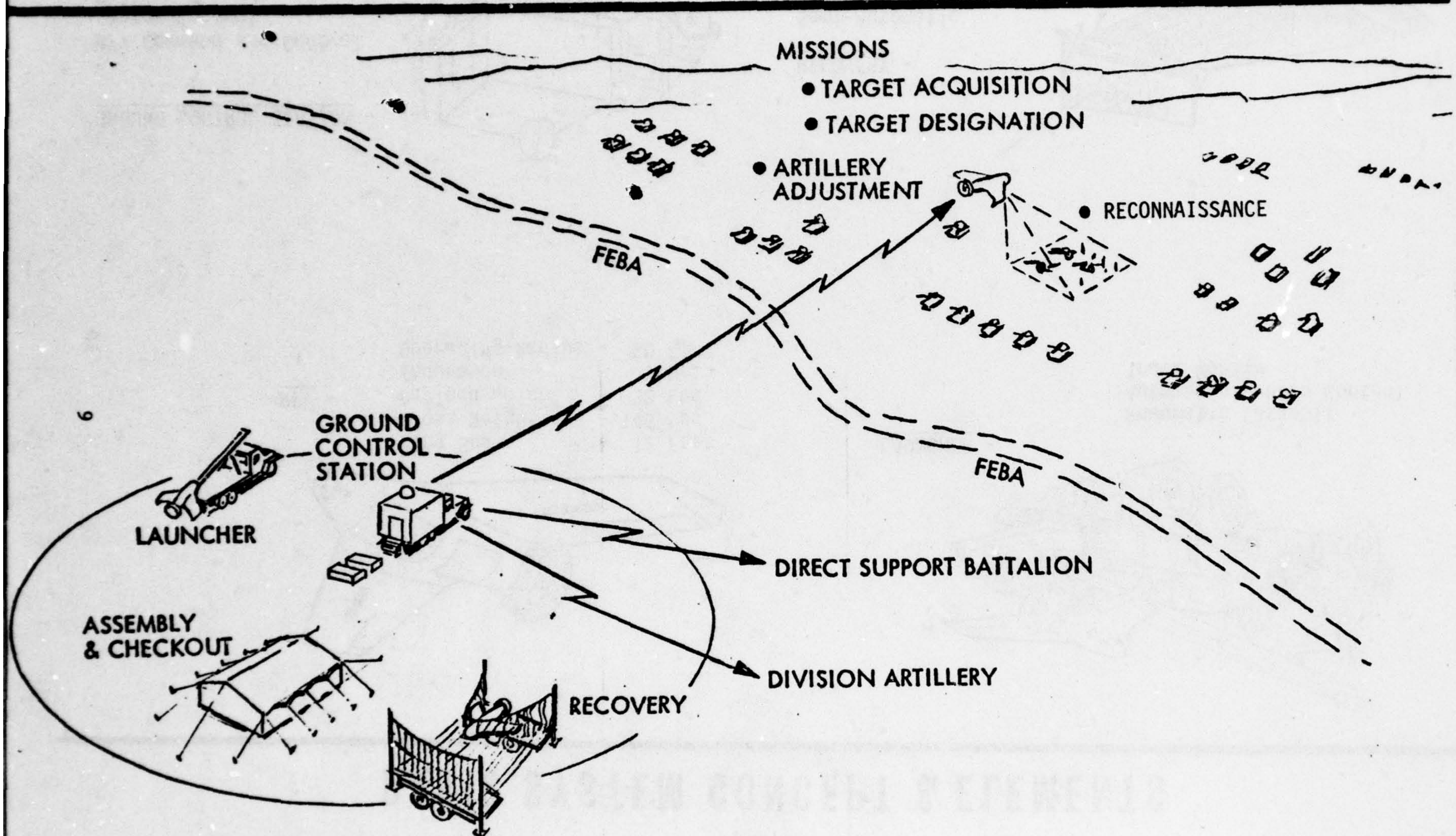
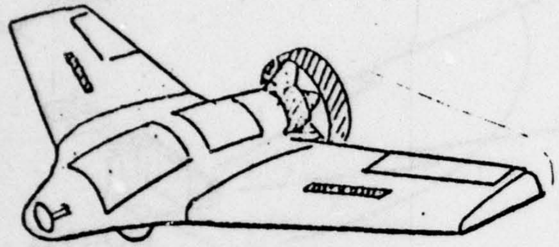


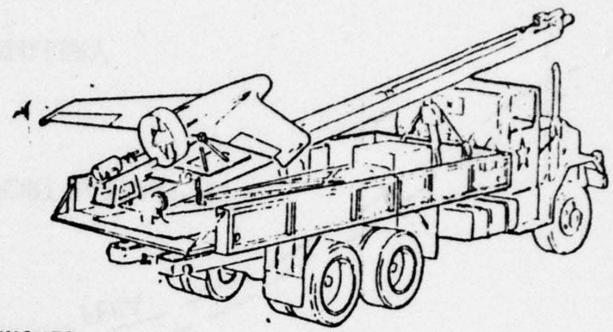
FIGURE 2.

BASIC SYSTEM CONCEPT & ELEMENTS



RPV -

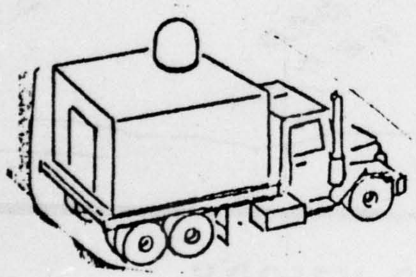
Wing Span	-	12 Feet
Gross Weight	-	146 Lbs
Payload Weight	-	38 Lbs
Endurance	-	3 Hrs
Operating Radius	-	20 Km



LAUNCHER -

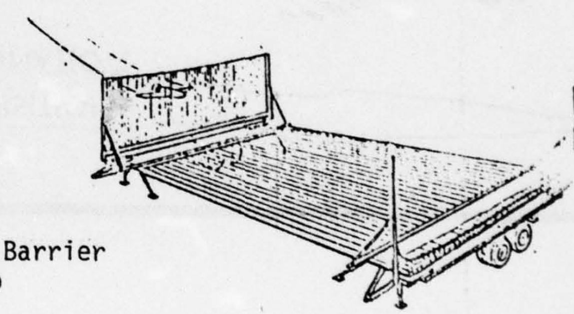
Pneumatic Catapult
Automatic Launch Control
Truck Mobile

GROUND CONTROL STATION -



RPV Command and Control
Sensor Control
Mission Records

RECOVERY -



Semi-Automatic
Trailer Mounted
Vertical Ribbon Barrier
Horizontal Strap

Such a restructuring of the program has occurred, largely for budget reasons, and the criticism does not apply to the program as now being evaluated.

Part of the success of the present program is due to its centralized program management. Its Development Manager's Office has resources and authority to access and direct the efforts of various Army Labs to meet program needs. Thus, for instance, sensors and a communications technology developed for other purposes, have been adapted to the RPV system. The program is considered an outstanding example of the utilization of exploratory and advanced (6.2 and 6.3) developments for a specific program.

On the negative side, the Development Manager's Office is considered understaffed in relation to the job it has to do. This situation will be aggravated as the program advances to the engineering development stage. The major portion of the work will then be done by outside contractors, rather than by in-house Army organizations. Furthermore, if a new prime contractor is involved, the prime burden of passing along the past experience to the development engineering phase of the program will fall on the Development Program Manager's Office. It is strongly recommended that this Program Office be more adequately staffed.

The relationship of the Army's program objectives to those of other Services was examined. Presentations were made to the Ad Hoc Committee by Air Force and Navy representatives on their RPV Programs. Objectives and mission requirements were sufficiently different so there was not a duplication of the Army Program. Periodic interservice meetings occur which exchange information on problems and solutions which may be common to the programs. Based on these limited presentations, it would appear that the Army is further along in its process of developing an operable system for its specific needs. Once this system comes into operation, it could be examined to determine its utility for mission requirements of the other Services, but at present, the independent developments are considered justified.

The extent to which the Program has benefited from technology developments from other sources is noteworthy. Prior ARPA programs contributed significantly. The sensor and ICNS data link systems were initially developed for other programs. AQUILA Program has been used for adaption of these subsystems to its specific requirements. In the reviews, it was also evident that most useful support was supplied by various Army laboratories. In this way, it was possible to accomplish more than might have been expected from a tight budget and a small program staff.

Present Status of Program.

Finding -

The AQUILA contractor demonstration program achieved 50 successful launches and recoveries out of the last 51 flights. At this point, on 11 July 1977, it was accepted by the Army for combined DARCOM/TRADOC testing at Fort Huachuca. The success of the system in contrast to the earlier flight experience was achieved, in part, by a switch from horizontal net to vertical net recovery. Experience in the early stages of the program also led to changes in manufacturing procedures--primarily, environmental tests of subsystems and prelaunch and checkout of the complete RPV. Deficiencies in the vehicle flight control program were uncovered and corrected. Flights of the TV/laser sensor on an Otter airplane developed familiarity with its use.

Conclusions and Recommendations -

The above described progressive effort resulted in a system with sufficient reliability and readiness for turnover to Army DARCOM and TRADOC crews for testing. The number of available vehicles for such a program may be marginal and may not allow for attrition and required spares.

In view of the importance of a timely completion of the TRADOC tests, it is recommended that top priority be given to maintaining the present planned schedule. No margin remains for unanticipated failures. Provisions should be made to avoid delays due to inadequate spares.

The AQUILA contractor acceptance tests not only demonstrated the system reliability, but also trained Army operators for the TRADOC tests. Out of the 51 flights prior to Army acceptance, all but one resulted in successful launch and recovery. The one failure is traceable to operational procedures (complicated by training a new operator). On the basis of this experience, it is concluded that the system has sufficient reliability and simplicity of operation to provide TRADOC with adequate means for performing their planned test program.

The main message of the flight history of AQUILA is derived from an analysis of the basic causes of the series of failures experienced during the early portion of the program. This experience is of significance to the conduct of the future program. There is a danger that an underfunded program will lead to a repetition of shortcut procedures leading to an unreliable system. This point is discussed in the concluding section of this part of the report.

Development Required For an Operational System.

Finding -

The AQUILA RPV system is being built with operational characteristics and components which will be adequate for its TRADOC "demonstration" purpose. In some respects, these will not be acceptable for an operational vehicle and will require upgrading and modification in the engineering development phase. In anticipation of this, approximately 99% of all Army RPV funding during the past year has been spent on AQUILA or on developments which will make suitable subsystems available for incorporation in the engineering development vehicle. (It is to be noted that these are all for the "first generation" operational vehicle.) These include:

Engine Development. Two contracts have been placed to develop a reliable lightweight engine of 20-horsepower to serve as a power plant for future RPV's. These new engines will be available toward the end of the present calendar year and will be a valuable asset for all future RPV developments, providing lightweight engines in a desirable horsepower range where none presently exists. Availability of a reliable engine in the 20-horsepower range appears to adequately cover future design requirements for RPV's.

ICNS Development. A contract has been placed for an Integrated Communication and Navigation System (ICNS) which will develop hardware which will be integrated and flight tested in a mini-RPV to demonstrate command and control and mission data retrieval in a hostile jamming environment.

Actuator. No appropriate actuators used at the present time--those now being used on the AQUILA--compromise its performance unduly.

Development contracts have been let for higher performance actuators at 25 and 50 inch/lbs.

Other features of AQUILA are deficient for an operational vehicle, but for a number of reasons including budget limitations, no development effort is being supported. These include:

Rate Gyro/Autopilot Normal Accelerometer. Past equipment had unacceptable bias and drift characteristics, but alternative equipment with adequate performance is available.

Control Van. This is probably now the most vulnerable subsystem. Means for improving, such as separating the van from the electromagnetic radiating elements, are being considered but will be deferred for incorporation in the engineering development phase.

Sensors. A lighter weight and less costly sensor subsystem appears feasible but will require some funded development effort. For budget reasons, this was deferred to FY 78.

Battlefield Operability. The AQUILA system is a very "soft" one capable only of operating in a relatively benign, nonhostile environment. Problems with the horizontal recovery system were solved by changing to a vertical recovery net. However, further improvements appear desirable to provide ease of launch and recovery in a battlefield environment.

Conclusions and Recommendations -

Experience on the AQUILA development program to date has highlighted certain technology developments and system improvements that are necessary if an RPV system capable of operating in the battlefield environment is to be developed. Such funds as have been available to the Program Office above those required to support the main AQUILA demonstrator program have been devoted to the more essential of the hardware developments which require long lead time.

The development of a lighter weight, lower cost TV/laser sensor optimized for mini-RPV use has been deferred due to lack of funds. System changes to improve operability and decreased vulnerability in the battlefield environment are such that they can be handled during the engineering development phase. While the focus of the limited development funds on "first generation" RPV requirements and the selection of priorities is endorsed, it is urged that budget provisions be made to fund developments to optimize the sensor assembly with respect to weight and cost. Such an optimization will have a significant beneficial effect on the cost effectiveness of an operational RPV since it now represents over 50% of the vehicle costs. Investment of modest funds at the present will result in significant cost savings on the production vehicles.

Discussion.

Consistent with its initial objective, the AQUILA system is a relatively "soft" system. It is adequate for its intended purpose--TRADOC evaluation of an RPV in a relatively benign environment--but a tactical RPV system needs to be significantly upgraded to harden it and give it the transportability, reduced vulnerability, and ease of operation required for a battlefield environment. Also, consistent with the "model airplane" concept at the outset of the program, it uses certain on-the-shelf, commercially available components. These include a "go-cart" engine, some low performance actuators, and low-cost gyros and accelerometers. No anti-jam or multi-vehicle capability is included in its communication subsystem; no special effort has been made to build transportability into its van-mounted electronics equipment and, a sensor assembly that could benefit by obvious weight and cost developments to optimize it for mini-RPV use. In addition to its individual components, the overall system needs modification from the standpoint of vulnerability and operability. The foregoing limitations do not compromise the AQUILA system to the extent that it will not be suitable for the TRADOC demonstration tests. However, it is already recognized that the ROC which will control the specifications for the engineering development vehicle will probably require upgrading of the above items. The technology developments funded under the RPV Program with a single exception are concerned with upgrading the subsystems that will go into the engineering development vehicle for the "first generation" system; i.e., not for future uses or improvements. These are the engine, actuators, and the communications system. These were selected because of their essential nature, and the lead time necessary for these hardware developments.

The development of a major item of sigificance is considered to be that of the Integrated Communication and Navigation subsystem. Technology developments involving spread spectrum, pseudo-noise and frequency-hopping techniques have been under development by ARPA and DDRE. However, no integrated system with both anti-jam and multi-vehicle communication capability existed. Thus, the major technology funding effort was directed at development of such an integrated system for an RPV. This effort--the Harris/CHIRP system--based on a combination of an adaptive antenna and spread spectrum approach--has now reached the point of evaluation testing on an Otter aircraft. (It is understood it has received the approval of a DDRE Committee set up to review command and control communication system developments throughout the DOD.) It is scheduled for later incorporation into the AQUILA for tests that will be conducted parallel to and concurrent with the TRADOC evaluation. The system should be ready for incorporation in the engineering development phase.

Other recognized development requirements have been deferred either because adequate higher grade subsystems (e.g., higher performance rate/gyro/accelerometer combination) are available or, in the case of vulnerability and operability, it is system modifications that are required rather than basic technology improvements requiring long lead time. These include improved transportability and hardening of all the equipment; possible simplification of the launch and recovery techniques for ease of field use; and a separation of the communication van from the radiating antenna to decrease its vulnerability.

In particular, alternatives to the present recovery method deserve further study. Parachute recovery, if feasible, offers the possibility of improvements.

A number of the desired improvements can be made in the engineering development phase of the program. Presumably, the TRADOC tests will uncover other desirable improvements. However, some earlier development effort would be desirable--though not essential--on the TV/laser subsystem. This sensor assembly represents 25% of the weight of the vehicle and in excess of 50% of its cost. The equipment as it now stands is an adaptation to mini-RPV use of equipment originally developed for other purposes. In the long run, it would be cost effective if there were further development to reduce the weight and cost of this major subsystem. This effort has been deferred for budgetary reasons. It appears that an upgraded sensor will not be available in time for incorporation in the engineering development vehicle. This item should command high budget priority in the future planning in the hope of making an improved sensor available for the first production vehicles.

Battlefield Use of RPV's.

Findi

As reviously noted, because of a severe limitation of funds, almost all Army RPV resources have been devoted to the AQUILA demonstration on technology developments that will support the engineering development of the "first generation" RPV.

Conclusions and Recommendations -

Although the RPV appears to provide a significant improvement in the Army's capability to locate targets and accurately deliver artillery fire on enemy armor and artillery, it is necessary to determine quantitively how this system contributes and compares with the overall fire support mission currently being performed by other means. A quantitative measure of the operational utility and basic rationale as to why the Army should develop and deploy an RPV system does not appear to be available. Therefore, it is recommended that the studies either in process, such as the COEA, or those being planned and directed by TRADOC, be modified to provide an overall assessment expressed in quantitative terms, on the impact of the RPV on the enemy.

Discussion.

Most of the design and performance studies completed to date treat the RPV system as a separate entity whereby it was evaluated in terms of its own performance rather than determining how it affected enemy forces and action. There is a need to define how this system will be integrated into the division, and further to expand in considerably more detail how the RPV system will be utilized in a scenario such as in Central Europe. Such factors as survivability of the GCS, tactical operation of the RPV, enemy CM action, and friendly CCM techniques--all might influence the design of various elements of the RPV. Therefore, it is recommended that a comprehensive study be conducted which (a) examines and establishes how the system should be incorporated into the appropriate Army elements, (b) defines the various interfaces requirements, and (c) evaluates and establishes various tactics and countermeasures which the RPV unit should employ under various tactical situations.

The target mix for RPV's consists of tanks, artillery, radar and communication centers and clusters of weapons behind the FEBA. RPV's ought to be able to assist in the destruction of these targets cheaper, with less manpower and have longer on-station time than, for example, an attack helicopter. However, some of these factors are probably not enough on which to base the development of a new weapon system. The Panel believes that a study is required (a) whereby the effect on the enemy of utilizing RPV's can be compared to other means, and (b) where the key design or performance parameters can be treated parametrically so that the resulting system and subsystem design is based upon such an analysis.

Plans For Engineering Development Phase.

Finding -

The conduct of the RPV Program has been influenced from its very inception by its superficial similarity to a model airplane. It was thought to be simple and to be feasible to build it from on-the-shelf components. If the present program to date has shown anything, it has demonstrated this not to be so. The upgrading in reliability in the demonstration AQUILA vehicle has been a result of introducing procedures more typical of weapons systems of at least the complexity of (for instance) a guided missile. In addition, developments have been initiated in subsystems; e.g., engines, actuators, communications equipment, which will be necessary if an operational vehicle is to be developed.

Conclusions and Recommendations -

The important conclusion to be derived from the foregoing findings is pertinent to the conduct of the next step of the program (assuming the TRADOC tests result in a recommendation for the production of an operational system.) This next step will be an engineering development phase. The success of this next phase is going to be strongly influenced by both the initial planned budget and the contractual approach on which it is premised.

It is not considered appropriate for the Ad Hoc Committee to make a specific recommendation in the above regard. However, concern is expressed with respect to two aspects of the present plan for the engineering development phase. If the TRADOC tests result in an urgent requirement by the user for an RPV capability, consideration should be given to a two-contractor engineering development phase to give added assurance of meeting the requirement date with an operable system. The present plan is based on a single thread success schedule and budget. Furthermore, the present plan involves the possibility that a new contractor will win the development phase on the basis of price, with the loss of the benefit of such learning and experience derived from the program to date--and a consequent increased risk of future delays.

Discussion.

The past history of the RPV Program indicates that it was initiated on the basis of its presumed similarity to a "model airplane." An initial presumption, therefore, was that it could be built cheaply by use of such on-the-shelf items as a go-cart engine, commercial actuator, radio control components, and unstabilized TVs. Also, that it did not require the environmental tests and checkout procedures such as might be applied to (for instance) a Hawk missile. This model airplane concept also failed to take into account such system complexities as automatic control and computer navigation necessary for an operable system.

The series of failures in Flights 7 through 13 caused a review of the program by both the contractor and the Army. One obvious change introduced into later successful flights was the use of a vertical net for arresting the forward motion of the vehicle in landing in place of the hook/horizontal net system. Other than this, no basic system changes were introduced. There was, however, a significant change in procedures. The importance of software was recognized; software verification and test were emphasized, and software change control improved. More emphasis was placed on ground-based simulation to validate the systems integration concepts prior to flight. Every RPV was checked out by being suspended and tethered to allow full engine and avionics operation under vibratory conditions, and under control of the ground control system. A number of other less significant changes almost all concerned with checkout and procedural matters were introduced. The result was 50 successful flights out of the next 51 flights.

The foregoing would only be of historical significance except for its implications relative to the future program. Many of the deficiencies noted, except the hook recovery system, were traceable to an inadequate budget and what might be called the "model airplane syndrome". Originally, the test demonstration program was budgeted at $8 million dollars or two contractors at $4 million dollars each. Presumably, the program prepared by the contractors was influenced by this low budget bogey; eight of the ten bids received were approximately $8 million--leading to the selection of only one contractor. (It now appears that it will cost $16 million dollars for one.) The deficiencies causing the flight failures clearly can be traced to the original inadequate budget, and the type of contractors' proposals that such a budget invited.

The question must be asked whether the foregoing experience has been adequately reflected in the future plans. The future budget plans for the engineering development phase call for a single contractor based on a new competition. This is a single thread success schedule and budget. It involves the possibility of the loss of the learning and experience derived from the program to date and a repeat of a costly short-cut approach under the pressure of an award on the basis of price. It does not seem appropriate for the Ad Hoc Committee to make a specific recommendation

on procurement matters such as this. However, it is legitimate to observe that the success of the program will probably be more strongly influenced by the adequacy of the budget and contractual approach than by any technical considerations. The lack of maturity and background of experience in the RPV field makes this statement of increased importance. In contrast to such fields as airplanes, missiles, and satellites where procedures, quality control, performance requirements, etc., are well established--the RPV field is still in the formative stage. An inadequate budget which does not reflect the lessons learned in the earlier part of the AQUILA program will result in a proposal that will not produce a reliable RPV system.

FUTURE PROGRAM

Introduction.

Relatively little study has been given to future potential missions for RPV's beyond a listing of these missions. The exception is a study of the daylight RSTAD mission. It is anticipated, for instance, that once a daylight RSTAD capability is attained, that a requirement will arise for the extension of this capability to nighttime and other obscured visibility conditions. The pace at which such an evoluation can be accomplished will therefore be based on the technology in the sensor field. The next section deals with a consideration of the present state-of-the-art of likely sensors, and the timeliness of this availability in relation to the RPV Program needs.

Other than sensor development, a question exists as to possible improvements in the RPV utility if a rotary wing vehicle were used. Initial planning was to carry on two parallel demonstration studies, which would be used to determine the merit of a rotary wing vehicle in comparison with a straight wing. Budget considerations prevented this. A look, therefore, was taken at the desirability of an Army initiated development of a rotary wing RPV as an alternate solution to a fixed wing RPV for "second generation" RPV requirements.

Advanced Sensors.

Finding -

Technology for sensors for future possible RPV missions has received only a small amount of funding from the RPV Program. The present program is focused almost exclusively on daytime, good weather reconnaissance, surveillance, target acquisition, target designation, and artillery adjustment, using daylight TV and laser target designation and ranging. Technology for these functions is available now. It is clear that the first future requirement will be to extend the same mission capability to nighttime and poor visibility conditions. Forward Looking Infrared (FLIR) thermal sensors hold promise for first providing such nighttime and poor visibility operation. FLIR technology is receiving substantial funding outside the RPV Program. Both the present and future missions discussed in the last section can benefit from (or may require) other sensors. These include solid-state TV cameras, low light level TV, alternative infrared sensors (FLIRs, MFPA FLIRs,

pyroelectric vidicon), millimeter wave imaging sensors and/or designators, flash sensors, acoustic sensors, electromagnetic detectors, (ranging from radio to gamma ray frequencies), and others.

Conclusions and Recommendations -

We endorse and recommend continuation of the present strategy which provides a relatively small amount of funding for new sensors technology from the RPV Development Office. In virtually every case, non-RPV program requirements provide much more motivation (and funding) for sensor technology development than the RPV Program can afford. The limited total funding in the RPV Program must be focused on the "first generation" system, as already discussed. In addition, at this juncture, there is no compelling evidence that a particular sensor technology, essential for a future mission, will not be ready when needed. On the other hand, the use of small contracts to explore the adaptation of particular sensors for RPV applications will get the attention of the developers (both elsewhere in the Army and in the contractor community) and can provide useful leverage for the RPV Program.

Discussion.

The present RPV Program is properly focused on the daytime RSTA mission, with emphasis on artillery adjustment. The presently planned sensor package includes a silicon vidicon TV camera (with sensitivity to 0.9 μm in the near IR and a 1.06 μm laser rangefinder/designator. As discussed above in the PRESENT PROGRAM section, the technology to provide this sensor package is available now, although the camera and laser systems optimized for the RPV application are not developed yet. Early flight tests are promising enough to give confidence that a satisfactory sensor package can be developed. Hopefully, cost and weight can be decreased, but present projections appear acceptable. To date, good use has been made of existing sensor technology, and appropriately modest funding has been applied to the development of a camera and a laser rangefinder/designator for the RPV application.

Future sensor requirements fall into two distinctly different categories. First, there is the need to improve the RSTA capability and to extend the "first generation" daylight system to provide nighttime and adverse weather operation. Second, there are several other completely different potential missions which would require different sensor/payload packages. Very little funding has been provided to explore sensors for future missions. This is appropriate, since the RPV Program cannot afford to support significant sensor development at this time. Furthermore, considerable sensor technology R&D (much of it for other applications) already is underway, notably at the Night Vision Laboratories and through ARPA programs. When the "first generation" RPV has demonstrated its daytime usefulness, the Army can proceed to the night/all-weather RSTA mission and to the alternative future missions. The latter need to be prioritized through appropriate system studies (see System Studies and Other Uses Section, following).

Improved RSTAD sensors especially for night and adverse weather use. The principal candidate RSTAD sensors to be considered as potential future replacement or supplements for the present vidicon and laser are listed in Table 1. Benefits, disadvantages, and date of availability are tabulated for each sensor.

Daytime solid-state TV imagers will be available before 1980. Eventually, they should replace the present daytime TV silicon vidicon on the basis of size, weight, and ruggedness (with essentially the same performance). Daytime TV imagers probably will provide more resolution and will remain less expensive than night/adverse weather imagers. It probably will be desirable to have both sensor packages in the inventory once a practical, affordable all-weather sensor has been developed, in spite of logistic considerations.

Low Light Level TV (LLLTV) devices probably are too expensive for a marginal nighttime capability. In addition, they may be too large to fit in the limited space available. The situation will improve as "third generation" photocathodes (made with III-V materials) are mated to solid-state CTD (Charge Transfer Device) readout circuitry. This advanced technology will not become available for operational application until about 1980.

Forward Looking Infrared (FLIR) sensor technology is available today to provide night and adverse weather imaging capability appropriate for RSTA and artillery adjustment. However, present sensors are heavy and expensive for an RPV. The choice between 3-5 µm and 8-12 µm FLIRs is not obvious. The 3-5 µm system will require less refrigeration, but will not penetrate smoke and fog as well as the 8-12 µm system. If the added refrigeration is not too expensive or heavy, the 8-12 µm system is to be preferred. Hopefully, the RPV Program can benefit from the current large MOD FLIR program. Future generation FLIR systems, using monolithic focal plane arrays (MFPAs) of detectors and associated solid-state multiplexing

electronics hold much promise for driving down cost and weight (without loss of performance), but will not be available for operational application before 1980. The MFPA technology is heavily funded by several DOD agencies and is being developed rapidly.

The pyroelectric vidicon provides infrared imaging with an inexpensive room temperature camera. (FLIR systems all require refrigeration which adds cost and weight.) Pyroelectric vidicons are available now, but lack the sensitivity of a good FLIR system. However, they should be evaluated for the night/adverse weather role, due to their cost and weight advantage. A pyroelectric sensor with solid-state CTD readout may become available after 1980. It will be more rugged and will offer additional reduction in cost and weight, but may provide no more performance than the present pyroelectric vidicon.

Millimeter wave radar technology eventually may provide a good night/adverse weather imaging capability. Penetration of weather, fog, and dust will be better than that of a FLIR system and much better than daytime TV can provide. Image resolution will be seriously degraded, however. It may turn out that only moving targets can be detected. A millimeter wave radar also can provide rangefinder/designator capability, also with reduced angular precision. The antenna required will be at least 8-12 inches in diameter (or a phased array can be used). There is considerable DOD interest in millimeter waves now, and the technology is moving ahead rapidly, but the impact on RPV systems will not come before 1980.

The technology of 1.06 μm laser rangefinders/designators is mature, and adaptable for the RPV application. It may be desirable to move to 10.6 μm to gain superior penetration of weather, fog, smoke, and dust. Technology to accomplish this change is being pursued now for other applications. If a 10.6 μm laser rangefinder/designator becomes available, it will be useful in an impaired-visibility scenario only if used in conjunction with an FLIR imager. This option should be developed by about 1980.

In addition to the relatively conventional RSTA sensors discussed above, there are several unconventional sensors (e.g., metal reradiation radar--METRRA, trace gas detector, magnetometer, gravitometer, acoustic detector, etc.). Some day, one or another of these may be useful for the RSTD mission, either alone or in conjunction with another sensor. Unconventional sensors are covered comprehensively in MERADCOM Report 2183, by T. M. Small, entitled, "Unique RPV Sensors and Their Effectiveness Against Logistic Targets," dated June 1976. Future developments in this field should be followed in case relevance to the RPV program develops. There also are additional conventional sensors which have been omitted due to shortcomings considered to be overriding at this time. These include:

film camera - not real time;

n-color IR - larger, more costly and further off than one-color IR;

laser line scanner - much too large and costly;

side looking radar - too large, costly (situation may improve);

flash sensing of glints - detection capability too limited;

radiac - limited to sensing radioactive emissions.

Sensors for alternative missions. As mentioned before, the current RPV Program is appropriately addressed almost exclusively to the RSTA mission. When the Program has successfully demonstrated the utility of the RPV for this mission, it will be desirable to evaluate the potential value of other missions such as communications relay, ECM (jamming), SIGINT and ELINT, emitter location, strike, nuclear radiation monitoring (RADIAC), and chaff dispenser. Appropriate systems studies will be needed to identify priorities among these possible missions. Current RPV programs in the Air Force and Navy are addressing some of these applications; use should be made of their studies, where possible.

Until the performance requirements for selected future missions have been specified, it is difficult to assess the readiness of available technology to provide the necessary RPV payloads. In general, however, it appears that the future missions listed above can be accomplished fairly easily using present state-of-the-art in sensors and electronics. Anticipated communication relay requirements are modest, compared with those satisfied by satellite relays. A microwave jammer carried into enemy territory by an RPV will require much less power than one located inside friendly territory; an RPV should be able to carry a respectable jammer. The receiver for a strike RPV which homes on a SAM radar need not be very sensitive. In short, although the missions need to be specified in more detail before definitive answers can be provided, it appears that most of these missions can be satisfied with existing state-of-the-art in sensors and electronics.

TABLE I: CANDIDATE FUTURE SENSORS FOR RSTAD MISSIONS

Sensors	Benefit	Disadvantages	Technology Available for Engineering Development
Current Silicon Vidicon	Daytime TV imaging	Daytime imaging only	Now
Solid State TV Imager	Daytime TV imaging Reduced size, weight More rugged	Daytime imaging only	Before 1980
Present LLLTV	Night imaging	Cost, size Marginal performance	Now
3rd Generation LLLTV	Night imaging Reduced cost, size, weight	Marginal performance	About 1980
Present FLIRs	Imaging at night and through adverse weather, smoke	Cost, weight Refrigeration required	Now
MFPA FLIRs	Same as FLIR Reduced cost, size, weight	Refrigeration required	About 1980
Pyroelectric Vidicon	Same as FLIR Reduced cost, size weight No refrigeration required	Less performance than FLIR Possibly marginal	Now
Pyroelectric with CTD Readout	Same as Pyroelectric Vidicon. Reduced cost, size, weight More rugged	Same as Pyroelectric Vidicon	After 1980

TABLE I: CANDIDATE FUTURE SENSORS FOR RSTAD MISSIONS (cont'd)

Sensors	Benefit	Disadvantages	Technology Available for Engineering Development
Millimeter Wave Radar	Imaging, ranging and designation at night and through adverse weather, smoke, dust	Seriously degraded imaging (resolution) Moving targets only? Large antenna required	After 1980
Current 1.06 μm Laser	Rangefinder/Designator	-	Now
10.6 μm Laser	Rangefinder/Designator Improved penetration weather, smoke, dust	Probably larger, heavier Possibly more expensive All weather capability available only if used with FLIR	About 1980

Rotary Wing Considerations.

Finding -

There are at present no efforts taking place in the United States on the development of rotary wing or VTOL RPV's with the exception of a small company funded effort at Convair Division of General Dynamics concerned with a ducted fan vehicle. There is a significant development effort in the United Kingdom on a rotary wing RPV, and we understand that a Memorandum of Understanding (MOU) will be signed in the near future giving the United States Army access to detailed information and data from this program.

A rotary wing RPV offers the prospect of eliminating the most awkward features of the AQUILA system, the large net recovery system as well as the launcher. Development of a simple and reliable parachute recovery system for the fixed wing RPV would mitigate to some extent this advantage of the rotary wing RPV. A rotary wing RPV on the other hand will be a considerably more complex airframe with attendant increase in maintenance and reduction in reliability. A rotary wing RPV will undoubtedly cost more than a fixed wing RPV, however, this cost difference is probably not significant since the vehicle cost is only a small part of the total system cost. The rotary wing vehicle offers also the ability to fly slowly and to hover in contrast to the fixed wing; however, the dependence of the vehicle survivability and the ability to detect and recognize targets on flight speed is not clear at this time. In addition to the basic airframe development, other technical risk areas associated with rotary wing RPV's which may require engineering developments, include the effect of vehicle vibration level on sensor performance, "power settling" problems in vertical recovery, safety, and effect of rotor downwash in operation from unprepared areas. The sophistication of the automatic flight control system required for either the fixed or rotary wing vehicle implies that the basic stability level of the rotary wing RPV is not particularly an issue.

Conclusions and Recommendations -

In view of the development program in the United Kingdom, and the expected MOU, taken with a tight funding situation, it is recommended that development of a rotary wing RPV not be undertaken by the Army at the present time. The Army should make every effort to monitor as closely as possible the program in the United Kingdom.

It is further recommended that a study be undertaken to examine the impact of flight speed and hovering ability on the survivability of RPV's and on the ability to detect and recognize targets to evaluate whether the basic flight characteristics of a rotary wing RPV offer advantages over a fixed wing RPV.

Discussion.

There are at present no Army funded programs for rotary wing RPV. There is a program in the United Kingdom to develop a rotary wing RPV and we understand that a Memorandum of Understanding (MOU) will be signed in the near future which will provide the Army with access to information and data generated by this program. The ASAP Ad Hoc Study Group, therefore, undertook examination of the desirability of an Army initiated development of a rotary wing RPV as an alternative solution to a fixed wing RPV for "second generation" RPV mission requirements.

In discussing the advantages and disadvantages of a fixed wing versus a rotary wing RPV configuration, it is convenient to examine separately the impact of the RPV configuration on the system and mission. First, the impact of the vehicle configuration on the system is considered. Interest in the rotary wing configuration stems primarily from the fact that the relatively large and bulky launch and recovery system associated with the fixed wing RPV would be unnecessary. This most obvious advantage of the rotary wing RPV in simplifying the ground based support equipment is obtained at the expense of increased mechanical complexity in the flight vehicle. If a simplified recovery system is developed for the fixed wing RPV, this advantage becomes less clear. A rotary wing RPV will require additional control actuators, linkages, bearings and mechanisms associated with components such as rotor hubs, blade pitch controls and main rotor transmission, resulting in increased maintenance and reduced reliability in contrast to the fixed wing vehicle. Attendant with this increase in vehicle complexity would be increased vehicle cost although this is probably not a significant factor since

vehicle cost is only a small fraction of total system cost. The automatic flight control system of a rotary wing vehicle would be more complex than the fixed wing system, but, again, this is probably not significant since any RPV will require a sophisticated automatic flight control system to permit it to be flown remotely to accomplish its mission.

The rotary wing vehicle offers good hover and low speed capabilities at the expense of payload for an equivalent gross weight and maximum speed. This trade-off is discussed further below.

One unanswered question regarding the rotary wing RPV is the impact of the vehicle vibration spectrum on sensor performance and life. Candidate sensors need to be exposed to vibration levels and frequencies which will be experienced on rotary wing RPV's to resolve this.

Other aspects of the rotary wing system which must be considered include possible problems with "power settling" in steep vertical descents, the influence of rotor downwash operating in a dusty environment, and safety of operation with comparatively high energy rotor systems operating in a horizontal plane.

Certain advantages in the data and communication links can be obtained through the use of a coaxial rotor configuration with an axisymmetric fuselage such that the orientation of the fuselage can be selected by the ground operator; e.g., a highly directional antenna can be used for the communication system. The antenna configuration is simplified and anti-jam protection is obtained at the expense of aerodynamic efficiency. This is the configuration selected in the United Kingdom.

Solutions to most of the problems mentioned above require engineering development and do not appear to present any unusual technical problems.

With respect to the mission, it is difficult to evaluate the advantages which might be gained from hovering and low speed performance at the expense of high speed. There does not appear to be sufficent data available to evaluate the effect of flight speed on sensor performance and consequently, on the ability of the operator to detect and recognize targets, as well as the impact of flight speed on survivability. Use of sensors with automatic tracking features appear to eliminate to a large extent the advantages of a hovering platform, however. If studies show (1) that there is a clear advantage to low flight speeds and hovering for target detection and recognition, and (2) that a low flight speed does not make the vehicle prohibitively vulnerable, then the rotary wing RPV should be given serious consideration. Otherwise, it appears that an extensive engineering development will be required to develop a reliable rotary wing RPV with acceptable maintenance levels, and that the best course for the Army to follow is to monitor closely the rotary wing RPV developments in the United Kingdom.

System Studies of Other Missions.

Finding -

As previously noted in various sections of this report, almost all of the resources allocated for the investigation of RPV's have been devoted to technology development, with only limited study of other potential missions. The Panel feels that the full potential and operation effectiveness of the RPV either in growth of the present "first generation" system or its utility in employing other payloads for other missions has not been adequately investigated.

Conclusions and Recommendations -

As a result of the majority of funds being expended on such subjects as (a) future mission applications and analyses, including a prioritization of capabilities; (b) quantitative assessment of the operational effectiveness of the RPV when employed in other missions; (c) technology development plans to support designated mission concepts and (d) a Master Program Plan relating the funding and scheduling of vehicles with extended or new operational capabilities to the development plan of the "first generation" system. If the present AQUILA transitions from Advanced Development into full scale Engineering Development, we believe that the potential of other missions such as (a) growth to day/night and adverse weather, (b) EW, and (c) longer operating range, necessitates the same type of quantitative assessment as that conducted for the Baseline System. Specifically, we recommend that a series of trade-off studies, under the direction of TRADOC, be conducted where various operational concepts and payloads are evaluated. Each of the alternate systems should be assessed in terms of operational effectiveness, using measures such as targets killed with and without the RPV, losses encountered with and without the RPV, or expected rate of enemy force travel with and without RPV's. Losses of friendly armor as well as Attack or RECCE helicopters should be included in a study of this type. From an

operations standpoint, realistic battlefield scenarios should be utilized where the analysis can consider variations in tactics; e.g., single or multi-vehicles, as well as enemy countermeasures.

Discussion.

It is intended that the "first generation" system will provide a day only, clear weather, Reconnaissance, (limited) Surveillance Target Acquisition (RSTA) capability to the Division. Specific operational requirements for this system are: (1) detect, identify, and locate targets accurately out to 20 KM beyond the FEBA; (2) designate targets for terminal homing munitions; and (3) adjust artillery fire.

A list of growth in capability of the Baseline System is shown in Table 1. In essence, near-term growth of the Baseline System includes: (1) extension from day, clear weather to day/night adverse weather with the addition of some electronic warfare capability; and (2) extension of range capability from 20 KM to 50 KM and utilizing updated technology for the RSTA, LD, LR, and EW sensors.

Essentially, the priorities established by TRADOC are to achieve a day/fair weather only RSTAD capability first, extend this capability to night, all weather, and then consider EW as a second priority. Since there are a number of potential applications of the RPV, the conduct of mission analyses and operational effectiveness studies should result in a definitive longer range plan for the "second generation" and beyond RPV.

Some examples of alternate missions being suggested in various Army documents are as follows:

SOME CANDIDATE RPV MISSIONS

- **Reconnaissance - Real-Time Radar and TV Imagery to Higher Commands**
- **Defense Suppression - Harass, Strike**
- **Strike - Kamikaze, Designate, Loiter and Strike**
- **Electronic Warfare - Chaff, Jamming, Decoys**
- **Communicate - Communication Relays**
- **Sensor Delivery - Ground Sensors**
- **Tactical Intelligence - ELINT, SIGINT, COMINT**

TABLE II

RPV MINIMUM SYSTEM CHARACTERISTICS

	1st GENERATION	FUTURE	
Minimum System Characteristics	MSC-2	MSC-2.5	MSC-3
Time Frame	1980	1980	1985
Mission Capability	RSTA, LR, LD	RSTA, LR, LD, EW	RSTA, LR, LD, EW
Range Band (KM)	3 - 20 (KM)	3 - 20 (KM)	3 - 50 (KM)
Day/Night & Adverse Weather	Day	Day/Night Adverse Weather (State of the Art)	Day/Night Adverse Weather

LD - Laser Designator
LR - Laser Ranger
EW - Electronic Warfare

FURTHER RPV MISSIONS TO CONSIDER

- Emplanting Beacons for Offset Homing by Indirect-Fire Weapons With Low-Cost Sensors
- Covert Intelligence Operations
- Psychological Warfare
- Controlled Delivery of Subkiloton Nuclear Warheads (if ADMs, Tube and Lance Deployments Were Forbidden by Rules of Engagement)

The Panel believes that there is great potential in the application of the RPV in various Electronic Warfare missions. There has been some study as well as some limited testing conducted at Fort Huachuca of the potential of mini-RPV's as SIGINT/EW platforms. Some of the possible SIGINT applications include (a) collecting and locating tactical voice communication centers, and (b) identification and location of counter-mortar/counterbattery and air defense radars.

A potentially very attractive mission for the RPV, which should be evaluated, is that of jamming enemy and/or dispensing chaff. In the jamming mode, advantages include being able to jam enemy communications equipment as well as air defense radar, by using the RPV to place an inexpensive jamming source close to enemy equipment. In this case, the tactics employed would, of course, significantly affect the operational utility of the RPV. For example, it would be interesting to evaluate the effectiveness (such as the improvement in RPV survivability) of utilizing a jammer RPV escorting attack helicopters or other RPV's while on an RSTA mission. Power requirements and space limitations for both spot and barrage jammers are, of course, constraints which must be studied to determine the technical feasibility of this concept.

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The Army's Remotely Piloted Vehicle (RPV) Program was reviewed. This review covered the AQUILA Program which was directed at the provision of a demonstrator vehicle for evaluation of the utility of an RPV for Reconnaissance, Target Acquisition, and Laser Designation (RSTAD). It also examines the adequacy of the available technology and ongoing development effort for implementing a daylight TV/laser-equipped mini-RPV suitable for operation in the battlefield environment. Finally, it looks into future potential uses by the

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of an RPV capability and the technology developments which will pace this use.

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